CLAIMS

What is claimed is:

1. A loudspeaker diaphragm having an acoustic region, the loudspeaker diaphragm comprising:

a first region having an inner and outer surface,

a second region radially inward of the first region and having an inner and outer surface,

a coating formed on at least one surface of the first and second regions;

where the coating tapers from a maximum value in the first region to minimum value in the second region.

2. The loudspeaker diaphragm of claim 1 where the coating comprises a continuous layer.

3. The loudspeaker diaphragm of claim 2 where the diaphragm is at least partially formed of aluminum, titanium, magnesium, an alloy of aluminum, titanium, magnesium, or combinations thereof.

4. The loudspeaker diaphragm of claim 3 where the coating is formed of a carbide, boride, nitride, or oxide.

5. The loudspeaker diaphragm of claim 4 where the coating has a thickness of from about 0.1 microns to about 8 microns in the second region and a thickness from about 2 microns to about 100 microns in the first region.

6. The loudspeaker diaphragm of claim 4 where the coating is an anodically formed oxide layer.

7. The loudspeaker diaphragm of claim 1 where the first region is substantially conical.

8. The loudspeaker diaphragm of claim 7 where the second region is substantially cylindrical.

9. The loudspeaker diaphragm of claim 8 where the first region comprises at least a

portion of the acoustic region of the diaphragm.

10. The loudspeaker diaphragm of claim 1 where the coating in the first region comprises a first area of substantially uniform thickness and a second area of non-uniform thickness.

11. The loudspeaker diaphragm of claim 10 where the second area of the first region is tapered.

12. The loudspeaker diaphragm of claim 11 where the first area is radially outward of the second area.

13. The loudspeaker diaphragm of claim 1 where at least portions of both the inner and outer surfaces of the first region are coated.

14. The loudspeaker diaphragm of claim 13 where at least portions of both the inner and outer surfaces of the second region are coated.

15. A loudspeaker diaphragm comprising:

a first region,

a second region,

a transition region between the first region and the second region, and

a continuous coating formed on at least one major surface of the first region, the second region, and the transition region, where the coating in at least the transition region is tapered.

16. The loudspeaker diaphragm of claim 16 where at least a portion of the coating in the first region is tapered.

17. The loudspeaker diaphragm of claim 16 where the coating in the second region is of substantially uniform thickness.

18. The loudspeaker diaphragm of claim 16 where the coating in the second region is tapered.

19. The loudspeaker diaphragm of claim 18 where the coating tapers from a maximum value in the first region to a minimum value in the second region.

20. The loudspeaker diaphragm of claim 15 where a one portion of the coating in the first region is tapered and another portion of the coating is of substantially uniform thickness.

21. The loudspeaker diaphragm of claim 20 where the portion of the coating of substantially uniform thickness is radially outward of the tapered portion.

22. The loudspeaker diaphragm of claim 15 where the diaphragm is at least partially formed of aluminum, titanium, magnesium, an alloy of aluminum, titanium, magnesium, or combinations thereof.

23. The loudspeaker diaphragm of claim 22 where the coating is formed of a carbide, boride, nitride, or oxide.

24. The loudspeaker diaphragm of claim 15 where the coating has a thickness from about 0.1 microns to about 8 microns in the second region and a thickness from about 2 microns to about 100 microns in the first region.

25. The loudspeaker diaphragm of claim 23 where the coating is an anodically formed oxide layer.

26. A loudspeaker diaphragm comprising:

a conical portion

a cylindrical portion,

and a coating formed on at least one major surface of at least the conical and cylindrical portions, where the coating tapers from a maximum value on the conical portion to a minimum value on the cylindrical portion.

27. The loudspeaker diaphragm of claim 26 where the coating is continuous.

28. The loudspeaker diaphragm of claim 27 where the coating tapers from a maximum value at the periphery of the conical region to a minimum value in the cylindrical region.

29. The loudspeaker diaphragm of claim 28 where the thickness of the coating in the cylindrical region is uniform.

30. The loudspeaker diaphragm of claim 27 where the thickness of the coating in an area

of the conical region adjacent the periphery of the conical region is uniform.

31. The loudspeaker diaphragm of claim 27 where the continuous coating is an anodically formed oxide layer.

32. The loudspeaker diaphragm of claim 27 including a dome attached to a surface of the coating on the conical region.

33. The loudspeaker diaphragm of claim 32 where the coating on conical region outside the dome is of uniform thickness and the coating on the conical region inward of the dome is tapered.

34. A loudspeaker diaphragm comprising:

an inner surface,

an outer surface, and

a continuous coating applied to each of the inner and outer surfaces,

where the coating on the inner surface is tapered.

35. A loudspeaker diaphragm of claim 34 where the coating on the outer surface is tapered.

36. A loudspeaker diaphragm of claim 35 where the coating on the outer surface is uniform.

37. A loudspeaker diaphragm of claim 34 where the coating on the outer surface is thinner than the coating on the inner surface.

38. A method for forming a non-uniform coating on a substrate comprising:

connecting a metal substrate to be coated as the anode of an electrochemical cell comprising at least one cathode and at least one electrolyte,

passing a current through the electrochemical cell,

controlling the current density distribution within the electrochemical cell, and

forming a coating on at least one region of a surface of the substrate,

where the rate of formation of the coating tapers from a first value in one region of the substrate to a second value in another region of the substrate.

39. The method of claim 38 where the substrate comprises a loudspeaker diaphragm.

40. The method of claim 38 where formation of the coating is performed in a single step.

41. The method of claim 38 where the coating is continuous.

42. The method of claim 38 where the controlling of the current density distribution comprises varying the path length of the electrical current between the cathode and the substrate surface to be coated.

43. The method of claim 42 comprising increasing the path length of the electrical current between the cathode and the substrate surface to be coated.

44. The method of claim 38 comprising positioning at least one non-contact mask between a cathode and a diaphragm surface to be coated.

45. The method of claim 44 where the non-contact mask comprises an insulating material.

46. The method of claim 44 where the non-contact mask is shaped to substantially conform to the shape of the substrate.

47. The method of claim 46 where the non-contact mask comprises a cone.

48. The method of claim 45 where the non-contact mask further comprises an electrically conductive portion.

49. The method of claim 48 comprising connecting the electrically conductive portion to the cathode.

50. The method of claim 39 comprising connecting a first cathode to the inner surface of the loudspeaker diaphragm and a second cathode to the outer surface of loudspeaker diaphragm to form first and second electrochemical cells.

51. The method of claim 50 comprising positioning a first non-contact mask between the first cathode and the inner surface of the diaphragm and a second non-contact mask between the second cathode and the outer surface of the diaphragm.

52. The method of claim 51 comprising forming a coating on the inner surface and the outer surface of the diaphragm.

53. The method of claim 52 comprising operating the first and second electrochemical cells under identical conditions.

54. The method of claim 52 comprising operating the first cell at a different average current density than the second cell.

55. The method of claim 54 comprising forming the coating on the inner surface of the diaphragm at a different rate than the coating on the outer surface of the diaphragm.

56. The method of claim 55 comprising forming a thicker coating on the inner surface of the diaphragm than on the outer surface of the diaphragm.

57. The method of claim 52 comprising forming a non-uniform coating on the inner surface of the diaphragm and uniform coating on the outer surface of the diaphragm.

58. The method of claim 57 comprising forming a tapered coating on the inner surface of the diaphragm.

59. The method of claim 44 where the distance between the diaphragm surface and the mask is from about 0.1 mm to about 20 mm.

60. The method of claim 59 where the distance between the diaphragm surface and the mask is from about 0.1 mm to about 5 mm.

61. The method of claim 38 where the coating comprises an oxide layer.

62. The method of claim 61 comprising forming the oxide layer by anodization.

63. The method of claim 62 comprising operating the cell at an average current density of at least 5 A/dm^2.

64. The method of claim 63 comprising operating the cell at an average current density of from about 10 A/dm^2 to about 300 A/dm^2.

65. The method of claim 64 comprising operating the cell at an average current density of from about 60 A/dm^2 to about 200 A/dm^2.

66. The method of claim 65 comprising operating the cell at an average current density of from about 80 A/dm^2 to about 120 A/dm^2.

67. The method of claim 66 comprising operating the cell at an average current density of from about 90 A/dm^2 to about 100 A/dm^2.

68. The method of claim 63 comprising operating the cell at a temperature of from about 0 to about 100 decrees Celsius.

69. The method of claim 68 comprising operating the cell at a temperature of from about 30 to about 80decrees Celsius.

70. The method of claim 69 comprising operating the cell at a temperature of from about 40 to about 60 decrees Celsius.

71. The method of claim 70 comprising operating the cell at a temperature of from about 45 to about 55 decrees Celsius.

72. The method of claim 44 where the non-contact mask comprises at least one perforation.

73. A method of forming a non-uniform anodic oxide coating on a metal substrate in a single anodizing step comprising:

connecting the substrate to be coated as the anode of the electrochemical cell including at least one cathode and at least one electrolyte,

passing a current through the cell,

causing a progressive reduction in the effective applied voltage at the electrolyte/anode interface, and

forming a non-uniform coating on the surface of the substrate,

such that the regions of the substrate surface further from the cathode are more thinly coated than the regions more proximate to the cathode.

74. The method of claim 73 comprising varying the path length of the electrical current between the cathode and the substrate surface to be coated.

75. The method of claim 74 where the thickness of the coating formed on the surface of

the substrate decreases with the distance of the surface from the cathode.

76. The method of claim 75 where the non-uniform coating is tapered.

77. The method of claim 73 where the coating comprises a continuous layer.

78. The method of claim 73 comprising positioning at least one non-contact mask between a surface of the substrate to be coated and at least one cathode.

79. The method of claim 73 comprising operating the cell at an average current density of at least 5 A/dm^2.

80. The method of claim 79 comprising operating the cell at an average current density of from about 10 A/dm^2 to about 300 A/dm^2.

81. The method of claim 80 comprising operating the cell at an average current density of from about 60 A/dm^2 to about 200 A/dm^2.

82. The method of claim 81 comprising operating the cell at an average current density of from about 80 A/dm^2 to about 120 A/dm^2.

83. The method of claim 82 comprising operating the cell at an average current density of from about 90 A/dm^2 to about 100 A/dm^2.

84. The method of claim 79 comprising operating the cell at a temperature of from about 0 to about 100 degrees Celsius.

85. The method of claim 84 comprising operating the cell at a temperature of from about 30 to about 80 degrees Celsius.

86. The method of claim 85 comprising operating the cell at a temperature of from about 40 to about 60 degrees Celsius.

87. The method of claim 86 comprising operating the cell at a temperature of from about 45 to about 55 degrees Celsius.

88. The method of claim 73 where the substrate comprises a loudspeaker diaphragm.

89. A method for forming a non-uniform oxide coating on at least one surface of a loudspeaker diaphragm in a single anodizing step comprising:

connecting a loudspeaker diaphragm to be coated as the anode of an electrochemical cell including at least one cathode and one electrolyte,

passing a current through the cell,

passing electrolyte over the surface of the diaphragm,

progressively reducing the effective applied voltage at the diaphragm/electrolyte interface, and

forming a non-uniform coating on the surface of the diaphragm.

90. The method of claim 89 where the coating is tapered.

91. The method of claim 89 where the coating is continuous.

92. The method of claim 89 comprising operating the cell at an average current density of at least about 5 A/dm^2.

93. The method of claim 92 comprising operating the cell at an average current density from about 10 to about 300 A/dm^2.

94. The method of claim 93 comprising operating the cell at an average current density from about 60 to about 200 A/dm^2.

95. The method of claim 94 comprising operating the cell at an average current density from about 80 to about 150 A/dm^2.

96. The method of claim 93 comprising operating the cell at an average current density from about 90 to about 100 A/dm^2.

97. The method of claim 89 comprising positioning at least one non-contact mask between a cathode and a surface of the diaphragm to be anodized.

98. The method of claim 97 where the distance between the diaphragm surface and the mask is from about 0.1 mm to about 20 mm.

99. The method of claim 98 where the distance between the diaphragm surface and the

mask is from about 0.1 mm to about 5 mm.

100. A method for forming a non-uniform coating on a metal substrate comprising:
connecting a metal substrate to be coated as the anode of an electrochemical cell,
passing a current through the electrochemical cell,
forming a coating on at least one region of a surface of the substrate,
means for controlling the current density distribution within the electrochemical cell such that the rate of formation of the coating tapers from a first value in one region of the substrate to a second value in another region of the substrate.

101. The method of claim 100 where the means for controlling the current density comprise varying the path of the current.

102. The method of claim 101 where the means for controlling the current density distribution comprise positioning at least one non-contact mask between a cathode and a surface of the substrate.

103. The method of claim 101 where the means for controlling the current density comprise passing a current of at least 5 A/dm^2 through the cell.

104. The method of claim 101 where the means for controlling the current density comprise operating the cell at a temperature from about 0 to about 100 degrees Celsius.

105. The method of claim 104 where the means for controlling the current density comprise operating the cell at a temperature from about 30 to about 80 degrees Celsius.

106. The method of claim 105 where the means for controlling the current density comprise operating the cell at a temperature from about 45 to about 55 degrees Celsius.